Section 4: Key Inquiry Topic – Energy

NOAA Ship *Okeanos Explorer:* America's Ship for Ocean Exploration. Image credit: NOAA. For more information, see the following Web site:
http://oceanexplorer.noaa.gov/okeanos/welcome.html

Oceans of Energy

Focus
Ocean energy

Grade Level
7-8 (Physical Science/Earth Science)

Focus Question
What forms of energy are found in the ocean, and how might these be used by humans?

Learning Objectives
- Students will describe forms of energy.
- Students will explain how different forms of energy are used by humans.
- Students will explain at least three ways that energy can be obtained from the ocean.

Materials
- Copies of *Ocean Energy Inquiry Guide*, one for each student group
- Copies of the *Micro-Hydro Electric Generators Construction Guide*, one for each student group
- Materials for constructing Micro-Hydro Electric Generators (For each student group)
  - 1 gal. plastic jug
  - 10 plastic spoons
  - 1 cork, 1.5 – 2 inches diameter
  - 300 ft enameled magnet wire, 24 gauge (Allied Electronics Part Number 214-3578 or equivalent)
  - Wooden dowel, 1/4-inch diameter, 10 inches long
  - Foamcore, approximately 9 inches x 12 inches
  - 4 - Ceramic or rare earth magnets (Radio Shack Part Number 64-1883 or equivalent)
  - Clear vinyl tubing, 1/4-inch inside diameter, 4 inches long
  - 4- brass paper fasteners, 1 inch long
  - Safety glasses, 1 pair for each student
- Tools and Supplies that may be shared among student groups
  - Inexpensive multimeter capable of measuring 0.1 volt AC (*e.g.* Extech MN15A)
  - 2 - Jumper cables (Radio Shack Part Number 278-1157 or equivalent)
  - Electric drill with 1/4-inch drill bit

- Scissors
- Vinyl electrical tape
- Ruler
- Awl, ice pick, or 3-1/2 inch nail
- Hot glue gun
- Glue sticks
- White glue
- Utility knife
- Pencil sharpener
- Felt tip marker
- Magnetic compass
- Wire cutters
- Gloves

Mention of commercial names does not imply endorsement by NOAA.

Audiovisual Materials

- (Optional) Images of ocean energy technologies (see Learning Procedure Step 1,) or computer projector

Teaching Time

Two or three 45-minute class periods, plus time for student research and hands-on inquiry

Seating Arrangement

Five groups of two to four students

Maximum Number of Students

32

Key Words and Concepts

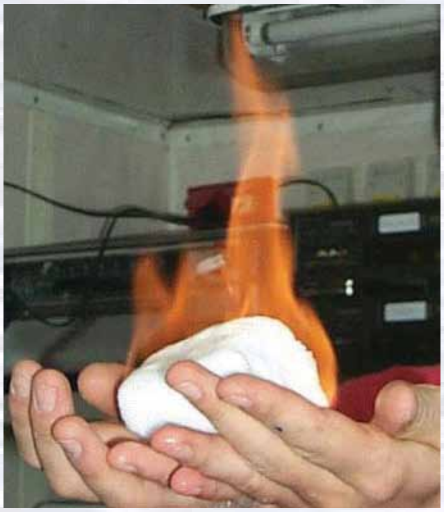
Energy
Salinity gradient energy
Wave energy
Tidal energy
Current energy
Thermal energy
Solar energy
Wind energy
Geothermal
OTEC
Methane hydrates

Background Information

NOTE: Explanations and procedures in this lesson are written at a level appropriate to professional educators. In presenting and discussing this material with students, educators may need to adapt the language and instructional approach to styles that are best suited to specific student groups.

The ocean is Earth's largest collector and storage system for solar energy, as well as the environment that receives a great deal of the heat energy produced by the Earth itself. The energy contained in Earth's ocean is enormous; a small fraction could power the world. Yet, humans presently use almost none of this energy.

Ocean energy exists in several forms, including heat energy, mechanical (motion) energy, and chemical energy. Methane hydrates are one example of an abundant potential energy source that is virtually untapped. Hydrothermal vents and undersea volcanoes are manifestations of geothermal energy that may also have significant



Methane hydrate looks like ice, but as the "ice" melts it releases methane gas which can be a fuel source. Image credit: Gary Klinkhammer, OSU-COAS

potential for human use. Because Earth's ocean is 95% unexplored, there are almost certainly yet-to-be-discovered areas that are particularly promising as sites for harvesting one or more forms of ocean energy. The mission of the NOAA Ship *Okeanos Explorer* is not specifically targeted toward developing ocean energy, but the ship's voyages of exploration will gather new information including undiscovered geologic formations, temperature gradients, currents, and geothermal processes that will contribute directly to efforts to enhance our use of ocean energy resources. Diving Deeper, page 25, provides an overview of ocean energy resources and some of the technologies being developed to harvest them.

This lesson guides student inquiries into various forms of ocean energy and some of the technologies used to capture this energy for human use.

Learning Procedure

1. To prepare for this lesson:
   - Review introductory information on the NOAA Ship *Okeanos Explorer* at *http://oceanexplorer.noaa.gov/okeanos/welcome.html*. You may also want to consider having students complete some or all of the lesson, *To Boldly Go*. . . .
   - Review the Learning Procedure steps, procedures on the *Ocean Energy Inquiry Guide*, and information in Appendix 1.
   - Assemble materials, tools, and supplies for the *Micro-Hydro Generator Construction* activity. Depending upon your students' manual dexterity and level of maturity, you may want to do some of the cutting and drilling in advance or recruit parent volunteers to assist with this preparation.
   - You may want to download images of various ocean energy technologies from the Web sites cited in Appendix 1, or bookmark these sites if you are using a computer projection system.

2. Provide each student group with a copy of the *Ocean Energy Inquiry Guide*, and have them complete Questions 1 and 2 (you may want to assign this as homework in a prior class). Briefly discuss the definition of energy as the ability to do work. Be sure students understand that this definition includes stored (potential) energy as well as working (kinetic) energy. Briefly discuss the various forms of energy. Students may have encountered some variation in terms and descriptions depending upon their specific research sources. For example, the term "mechanical energy" is sometimes confined to potential energy of objects under tension, while the kinetic energy of objects in motion is described as "motion energy." Key points include:
   - **Thermal Energy (Heat)** – kinetic energy of vibration and movement of atoms and molecules within substances; increasing thermal energy causes atoms and molecules to move and collide more rapidly
   - **Radiant Energy (including Light, Radio Waves, Microwaves, and X-rays)** – kinetic energy of electromagnetic waves; some definitions refer to radiant energy as the kinetic energy of a stream of photons, since some properties of electromagnetic waves resemble properties of particles; according to quantum field theory, both definitions are correct
   - **Mechanical Energy** – potential energy stored in objects by tension, such as compressed springs and stretched rubber bands; kinetic energy in moving objects and substances
   - **Electrical Energy** -- kinetic energy of electrons moving through a conductor
   - **Chemical Energy** -- potential energy stored in the bonds of atoms and molecules

- **Nuclear Energy** – potential energy stored in the nucleus of an atom
- **Gravitational Energy** – potential energy stored in an object that may be accelerated by a gravitational force; if an object is raised above Earth's surface it may be accelerated by Earth's gravity; gravitational energy increases with increasing height and/or mass of the object
- **Sound Energy** – kinetic energy moving through a substance (such as air or water) in waves causing the substance to vibrate

Be sure students understand that our experience with energy frequently involves conversions between these forms. For example, when we use electrical energy in a battery, that energy results from a conversion of chemical energy in the components of the battery to electrical energy of electrons moving through a circuit. Similarly, when we feel heat from the sun, we are experiencing a conversion of electromagnetic energy from the sun to thermal energy in the atoms and molecules of our bodies. In the latter example, there actually are additional conversions involved in our "feeling" the heat: the thermal energy in our bodies is converted to chemical energy in nerves that causes a series of chemical reactions that eventually cause our brain to perceive the heat.

You may also want to remind students about the First and Second Laws of Thermodynamics:

First: Energy can be changed from one form to another, but cannot be created or destroyed.

Second: Converting one form of energy into another form always involves a loss of usable energy.

Make sure students understand that the electricity we use is a secondary source of energy (sometimes referred to as an "energy carrier"). Since we are not presently able to capture and control natural sources of electricity (*e.g.*, lightning), we have to use another energy source to make electricity. The chemical energy of coal and petroleum fuels, the mechanical energy of moving water or wind, and the nuclear energy of radioactive materials are common primary energy sources that are converted into electrical energy. The reason for doing this is that it is much easier to move electricity than it is to move coal, wind, or nuclear fuels. Point out that the problem of how to capture, control, and distribute energy from a given source is a key issue in developing new energy sources for human activities. Hydrogen is another energy carrier that is being considered for storing and transporting excess energy produced from offshore ocean energy sources such as wind, solar, and waves (*http://ocsenergy.anl.gov/guide/hydrogen/index.cfm*).

3. Briefly discuss the mission of NOAA Ship *Okeanos Explorer*, highlighting the fact that 95% of Earth's ocean is unexplored, and the potential importance of ocean exploration to major issues facing our society. Brainstorm various sources of energy that may be found on and in the ocean, and record these on a list that is visible to the students. Ideally, the list will eventually include:

   Salinity Gradient (Osmotic) Energy
   Wave Energy
   Tidal Energy
   Current Energy
   Thermal Energy
   Solar Energy

Iceworms *(Hesiocaeca methanicola)* infest a piece of orange methane hydrate at 540 m depth in the Gulf of Mexico. During the Paleocene epoch, lower sea levels could have led to huge releases of methane from frozen hydrates and contributed to global warming. Today, methane hydrates may be growing unstable due to warmer ocean temperatures. Image credit: Ian MacDonald. *http://oceanexplorer.noaa.gov/explorations/06mexico/background/plan/media/iceworms_600.jpg*

Wind Energy
Hybrids
Methane Hydrates

It is not very likely that students will mention all of these; that's okay, just leave unmentioned sources off the list for now. For each energy source on their list, have students discuss how the energy might be captured, controlled, and distributed in a useful form. In many cases, this will involve converting the energy to electricity. Briefly review the basic process through which most electricity is produced:

The fundamental principle underlying electricity generators was discovered in 1831 by Michael Faraday: When a magnet is moved inside a coil of wire, an electrical current flows in the wire. The basic parts of a generator are a series of insulated coils of wire arranged to form a stationary cylinder, a magnet that rotates inside the cylinder, and a source of energy (because electricity is a SECONDARY energy source) to rotate the magnet. Steam turbines, internal-combustion engines, gas combustion turbines, water turbines, and wind turbines are the most common devices used to rotate the magnets in electricity generators. Steam turbine power plants powered by coal and nuclear energy produce about 70% of the electricity used in the United States. These plants are about 35% efficient, which means that for every 100 units of primary energy are consumed by the generator, only 35 units are converted to usable electricity.

Assign one or more ocean energy sources from the complete list (above) to each student group. Provide each group with a copy of the *Ocean Energy Inquiry Guide*. You may also want to provide some of the references cited in Step 1, or allow students to discover them on their own—a Web search on "ocean energy" will produce most of these and millions of others (no kidding!). Have students complete the remaining questions on the *Inquiry Guide*, as well as the Micro-Hydro Electric Generator activity.

Note: Students may also mention biomass as a potential form of ocean energy. Marine algae have been cultivated for centuries as food, and a variety of projects have been proposed that use seaweed as a feedstock for biofuels and electricity generation (biopower). Only a few small-scale projects have actually been implemented, and biomass is not normally included in discussions of ocean energy. Even so, marine biomass may prove to be important on a local scale, and you may want to add this to the list for students' inquiry.

4. Have each student group present the results of their inquiries, then lead a discussion of which ocean energy technologies appear to be most promising. Students should realize that energy storage and distribution are major issues for all of these technologies. Ask students whether there are other types of "energy carriers" that may be useful in addition to electricity and hydrogen. If a hint is needed, suggest considering the various forms of energy discussed in Step 2; could one or more of these provide an alternative energy carrier? A land-based example is using wind power to pump water into an elevated reservoir, so that it can be released in a controlled way through an electricity-generating turbine when electricity is needed.

The BRIDGE Connection

http://www2.vims.edu/bridge/DATA.cfm?Bridge_Location=archive1005.html – An activity guide: Waves – An Alternative Energy Source

The "Me" Connection

Have students write a brief essay describing how they might use alternative energy resources to significantly reduce their personal consumption of energy derived from fossil fuels.

Connections to Other Subjects

English/Language Arts, Mathematics, Social Studies

Assessment

Students' responses to *Inquiry Guide* questions and class discussions provide opportunities for assessment.

Extensions

1. Follow events aboard the *Okeanos Explorer* at *http://oceanexplorer.noaa.gov/okeanos/welcome.html*.
2. Visit *http://www.re-energy.ca* for additional hands-on renewable energy projects.
3. Visit *http://www.simplemotor.com/*, a site originally established by an 11th grade student to share his investigations into easy-to-build electric motors.

Other Relevant Lesson Plans from NOAA's Ocean Exploration Program

(All of the following Lesson Plans are targeted toward grades 7-8)

Friendly Volcanoes (Submarine Ring of Fire 2004 Expedition)
http://oceanexplorer.noaa.gov/explorations/04fire/background/edu/media/RoF.friendlyvol.pdf

Focus: Ecological impacts of volcanism in the Mariana Islands (Life Science/Earth Science)

Students will describe at least three beneficial impacts of volcanic activity on marine ecosystems and will explain the overall tectonic processes that cause volcanic activity along the Mariana Arc.

How Does Your Magma Grow?
(from the 2005 GalAPAGos: Where Ridge Meets Hotspot Expedition)
http://oceanexplorer.noaa.gov/explorations/05galapagos/background/edu/media/05galapagos_magma.pdf

Focus: Hot spots and midocean ridges (Physical Science)

Students will identify types of plate boundaries associated with movement of the Earth's tectonic plates, compare and contrast volcanic activity associated with spreading centers and hot spots, describe processes which resulted in the formation of the Galapagos Islands, and describe processes that produce hydrothermal vents.

It's Going to Blow Up!

(from the New Zealand American Submarine Ring of Fire 2005 Expedition)
http://oceanexplorer.noaa.gov/explorations/05fire/background/edu/media/rof05_explosive.pdf

Focus: Volcanism on the Pacific Ring of Fire (Earth Science)

Students will be able to describe the processes that produce the "Submarine Ring of Fire," explain the factors that contribute to explosive volcanic eruptions, identify at least three benefits that humans derive from volcanism, describe the primary risks posed by volcanic activity in the United States, and will be able to identify the volcano within the continental U.S. that is considered most dangerous.

Other Resources

See page 215 for Other Resources.

Send Us Your Feedback

We value your feedback on this lesson, including how you use it in your formal/informal education settings.
Please send your comments to:
oceanexeducation@noaa.gov

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Ocean Energy Inquiry Guide

Background Research

1. What is the definition of energy?

2. List and briefly describe eight different forms of energy.

3. Your teacher will assign your group one or more ocean energy resources to investigate. Your research should include:

Assigned energy resource:

- Identification of the type of energy involved (radiant, mechanical, etc.);

- A description of technologies that can be used to capture energy from this resource;

- Information about installations that are proposed or are actually using these technologies to obtain energy; and

- Identification of major problems or obstacles to obtaining useful energy from this resource.

4. What kind of information might be obtained by the NOAA Ship *Okeanos Explorer* from unexplored areas in Earth's ocean that could enhance understanding and potential development of this ocean energy resource?

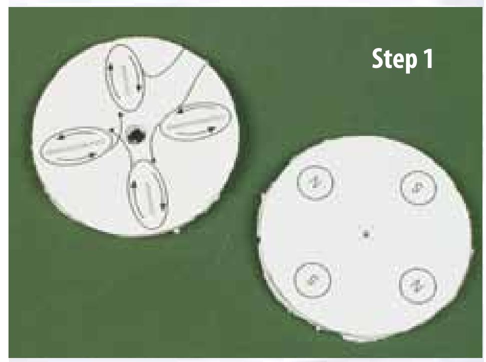
Micro-Hydro Electric Generator Construction Guide

Construction Procedure

Read ALL of the directions before beginning construction.

When a magnet is moved inside a coil of wire, an electrical current flows in the wire. The basic parts of a generator are a series of insulated coils of wire, one or more magnets, and a source of energy to rotate the coils or the magnets. The generator you are about to build consists of four coils that remain stationary (called the stator), four magnets that rotate around the coils (called the rotor), and a paddle wheel that can capture the energy of falling water.

1. Hot glue the patterns for the rotor and stator (found on Page 143) onto a piece of foamcore. When the glue has dried, use a utility knife to cut the rotor and stator disks from the foamcore sheet. Wear gloves when using the utility knife, and be careful! Use a cutting board, piece of scrap wood or several sheets of cardboard as a cutting surface.


Step 1

2. Use an awl, ice pick, or 3 1/2 inch nail to punch a small hole through the center of the rotor disk as indicated on the pattern. Use the utility knife to make a hole approximately 1/2-inch diameter in the center of the stator disk. Cut four slits through the disk as indicated.

Step 2


Assemble the Stator

3. Make a form for winding your coils by cutting a 1 1/4 inch x 3 1/4 inch piece of cardboard, folding it in half, and taping the ends together with electrical tape. This form is called a jig.

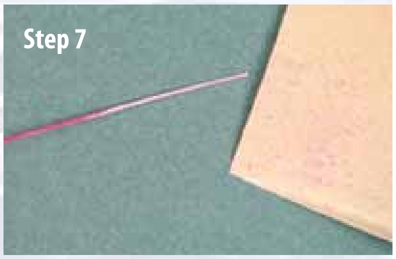

Step 3

4. Cut eight pieces of electrical tape about 3 inches long, and set aside.

5. Leaving a lead of about 3 inches, begin winding the first coil on the cardboard form. Wrap 200 turns, keeping the turns close together to form a tight coil.

Step 5


6. Slip the coil off the jig and secure the wraps with two pieces of electrical tape. Be sure you have leads about 3 inches long at both ends of the coil.



7. Use a small piece of sandpaper to remove about 3/4-inch of the enamel insulation from the ends of both leads.

8. Repeat Steps 5 through 7 to make three more coils.

9. Lay the coils on the stator disk in the position shown on the pattern. Arrange the coils so that their windings alternate between clockwise and counterclockwise. THIS IS VERY IMPORTANT! When you are sure you have arranged the coils correctly, connect adjacent coils by twisting the bare ends of the leads together. Be sure to leave two leads unconnected as shown on the pattern and in the photograph. Cover the twisted connections with short pieces of electrical tape.

10. Check your connections by setting your multimeter to measure resistance (ohms) and connecting the leads of the multimeter to the two free ends of the stator coil assembly. If your connections are good, the resistance should be very low (about 10 ohms or less). If the resistance is very large, two or more of the connections are not good, probably because the enamel insulation was not completely removed from the ends of the wires. Note that this test does not check whether you have correctly arranged the coils with alternating clockwise-counterclockwise windings.

11. Hot glue the coils to the stator disk in the positions indicated on the pattern. Lift the coils one by one, put a large glob of glue onto the disk where the coil touches, and press the coil into place. Let the glue solidify before gluing the next coil.

Step 12

Assemble the Rotor

12. Use a magnetic compass to determine the north and south pole of each magnet. Mark the polarity on the appropriate faces of each magnet.

Step 13

13. Attach the magnets to the rotor disk as indicated on the pattern. Put a small glob of glue onto the pattern, then press the magnet into place. Be sure you have alternating north and south poles facing up.

Assemble the Paddle Wheel

14. Put a blunt point onto the ends of the wooden dowel with a pencil sharpener.

15. Drill a 1/4-inch hole in the exact center of the cork. Be careful when using the electric drill! Wear eye protection and gloves. Be sure the cork is firmly clamped or held in a vise.

16. Center the wide end of the cork on the Marking Guide on Page 143, and mark eight cutting points on the cork with a pencil or pen.

17. Place the wide end of the cork flat on a cutting surface, and use the utility knife to make shallow slits where the ends of the spoons will be inserted. Be careful! Wear gloves!

18. Use wire cutters to cut the handles off of eight plastic spoons. Leave about 3/8-inch of the handle attached to the bowl of each spoon.

19. Insert the spoons into the slits in the cork. Push one spoon into each slit first, to slightly widen the slits. Then assemble the paddle wheel by pushing each spoon as far as it will go into each slit. Adjust the spoons as necessary so that they are evenly spaced and stick out of the cork at the same angle. When you are satisfied with the arrangement of the spoons, glue each one into place with some hot glue.

Assemble the Generator

20. Cut the bottom off of the plastic jug. Hold your paddle wheel inside the jug to determine how it needs to be oriented so that it can spin freely when attached to the dowel. If your jug has a handle on the side, this may interfere with the paddle wheel rotation unless it is properly oriented.

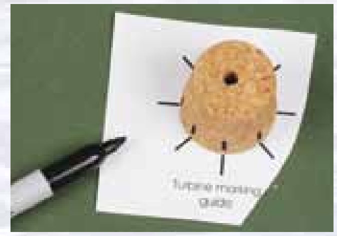
21. Use a ruler to find the center of the two sides that will support the dowel. Mark the center with a felt tip marker, being sure to allow enough space inside the container for the paddle wheel to rotate freely.

22. Drill a 1/4-inch hole through each of the marked points. Be careful! Wear eye protection and gloves.

23. Test-fit the dowel through the holes. If it seems to stick, slightly enlarge the holes with the drill or utility knife.

24. Place the stator assembly on the outside of the container so that the stator's center hole is over the hole in the container. Push an awl, ice pick, or nail through the slits in the stator disk to mark their location on the container. If the side of the container slopes away from one of the slits, that is okay; three attachment points are enough to hold the stator in position.
25. Use the utility knife to make four small slits on the side of the container to match the slits on the stator disk. Be careful! Wear gloves.

Steps 15 & 16



Step 17

Step 18

Step 19

Steps 20, 21 & 22

Step 26a

Step 26b

Step 28

Step 29

Step 31

Step 32

(PVC pipe apparatus used to support generator for the photograph)

26. Attach the stator disk to the container with brass paper fasteners. Bend the tabs of the fasteners flat against the inside of the container.

27. Cut four pieces of vinyl tubing, each about 1/2-inch long.

28. Slide one piece of vinyl tubing onto the dowel, about 3 inches. Push the other end of the dowel through the hole in the stator, and slide another piece of vinyl tubing onto the dowel from inside the container.

29. Position the paddle wheel inside the container and slide the cork onto the dowel. Slide a third piece of vinyl tubing onto the dowel, then push it through the hole in the side of the container. Slide the fourth piece of vinyl tubing onto the dowel from outside the container. You may have to adjust the various pieces of vinyl tubing during these steps.

30. Spin the shaft to be sure it turns without binding and so that the paddle wheel does not hit the sides of the container as it spins. Adjust the pieces of vinyl tubing to hold the shaft in the correct position.

31. Slide the rotor disk onto the dowel so that the magnets face the stator coils and are about 1/4-inch or less from the coils. Adjust the rotor so that it spins without wobbling and without having any of the magnets hit the coils. Use hot glue to hold the rotor in the appropriate position on the dowel.

Test Your Generator!

32. Place your assembled generator under a faucet so the water will hit the spoons and turn on the water. The rotor should spin rapidly. Set your multimeter to measure AC volts, and connect the leads of the multimeter to the two free ends of the stator coil assembly. Measure the voltage produced by your generator.

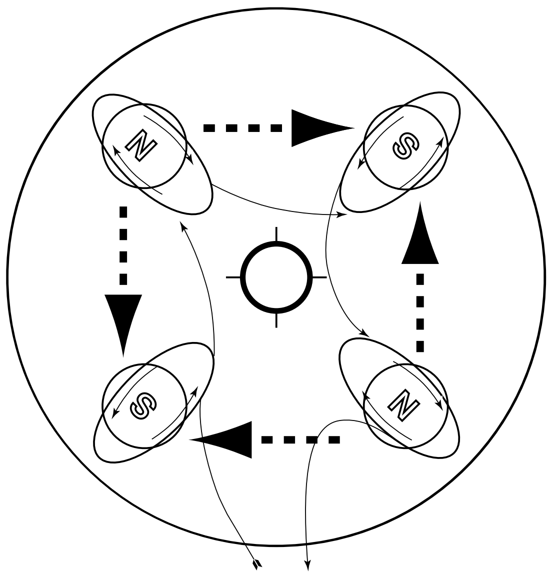
How It Works

When a coil of wire moves through a magnetic field, an electric current is produced in the coil. If you hold the coil in your right hand with your fingers curled around it, so that your fingers point in the direction of the magnetic field, your thumb will point in the direction of conventional current flow. This is called the Right Hand Thumb Rule.

Notes:
1. The direction of a magnetic field is from north pole to south pole.
2. Conventional current flow is related to Benjamin Franklin's theory of electricity, which was that electric current flows from positive to negative. We now know that electric current is the flow of electrons, which move from negative to positive. So conventional current flow is the opposite of the actual direction in which electrons move, which is called electron flow.

Referring to Figure 1, when the magnets of the rotor are positioned on top of the coils of the stator, conventional current flow through the coils is as indicated by the arrows. Notice that the direction of conventional current flow is opposite in adjacent coils, which is why you had to orient the stator coils with alternating clockwise and counterclockwise winding. When the rotor spins one-quarter turn to the position indicated in Figure 2, current flow through the coils is reversed, which is why your generator produces alternating current.

Figure 1



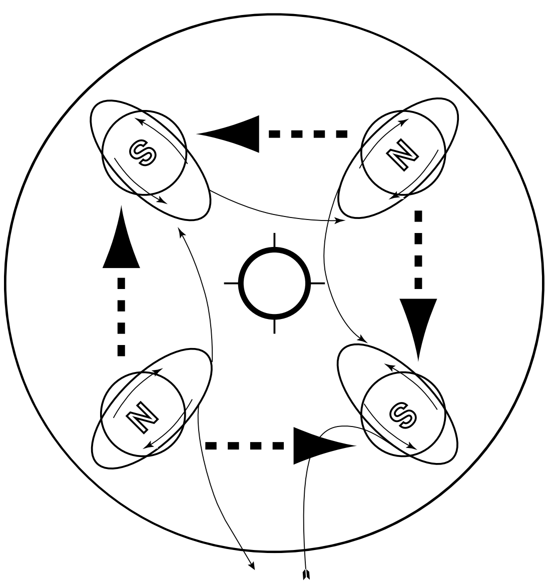
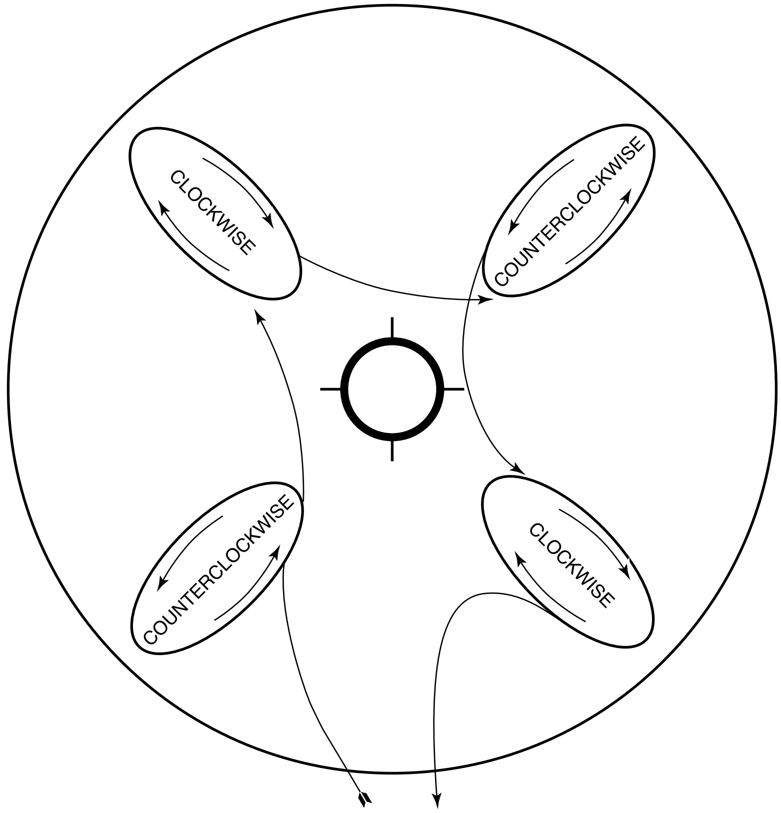
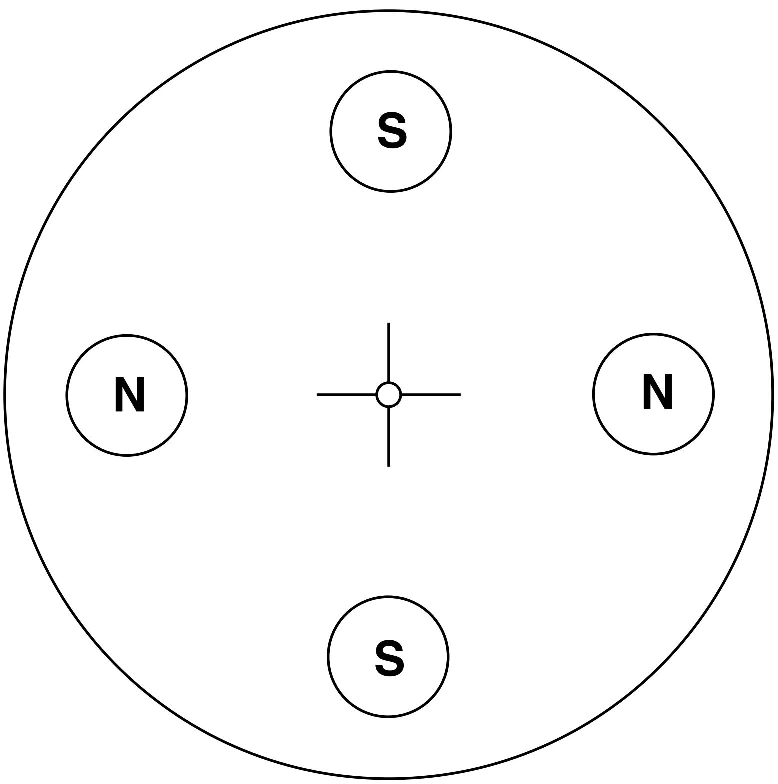


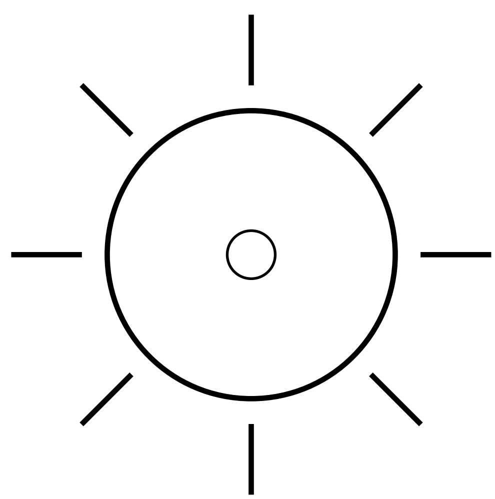
Figure 2

Stator Pattern





Rotor Pattern



Marking Guide

Notes: